Department of Physiology

Umm Al-Qura University

Physiology I

Course Description

Course number: 1804251-3

First Semester

1432-1433 / 2010-2011

3 CREDIT HOURS

2nd Year Pharmacy

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➢ INTRODUCTION

Physiology is the study of functions and mechanism of living organisms. Human physiology is a course that addresses the processes and mechanisms that are characteristic of human life with an emphasis on several important systems and how these systems interact with each other for maintenance of homeostasis of the organism as a whole. The objectives of this course are to provide students with fundamental concepts of how normal systems work, upon which an understanding of consequences in disease states can be built. The material will be presented under several major topic areas: general physiology and biological molecules, muscle, endocrine, gastrointestinal, cardiovascular, respiratory, renal and neurophysiology. These units will be integrated as the course progresses. The study of intrinsic and extrinsic control systems and how they help maintain homeostasis is of prime importance in physiology. An Attempt will be made to emphasize understanding the fundamental processes and on problem solving rather than on memorization and recalling excessive amounts of "facts".

Course Goal:

This course focus on physiology of different systems of human body.

Course Objectives

On successful completion of this subject, students will be able to (knowledge):

1. Explain the normal functioning of all the organ systems of the body and their interactions.
2. Recognize the contribution of each organ system to the maintenance of homeostasis.
3. Elucidate the physiological aspects of normal growth and development.
4. List the normal values of important physiological parameters and interpret such value when given.
5. Describe the physiological response and adaptations to environmental stresses.
6. List the physiological principles underlying pathogenesis and treatment of disease.

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At the end of this course the student will be able to (Skills):

1. Perform experiments designed either primarily for the study of physiological phenomena or for assessment of function.
2. Analyze and interpret experimental/investigative data critically.
3. Distinguish between normal and abnormal data derived as a result of tests which he/she has performed and observed in the lab.

Evaluation Procedures:

The department recommends that students know the objectives and methods of evaluation. Evaluation is not meant to cause stress, anxiety or panic. It is designed to serve the following purpose:

a) To justify student's promotion from class to class.
b) To provide students and teachers with information regarding progress achieving the stated objectives.
c) To reveal& correct gaps of knowledge if any.

One hundred marks are allocated for the course of **physiology I**. The evaluation is done by continuous assessment and final examination during the first semester as follows:

1st semester mark distribution

Examination	Marks
Theory:	
* Total mark for Midterm exam	25
* Final (end of semester) exam	50
Practical:	
* Total mark for Midterm Lab	8
* Total mark of Final Lab	8
Assignments:	
* Total mark for tutorials, study case, and assignments	9
Total mark	**100**
Note: The total mark allocated for each semester is 100 marks	

The written examination of midterm exam can include multiple choice questions, true and false; fill in the blanks and short essay questions in addition to illustrative diagrams. The final exam consists only of multiple-choice questions.

Summative Evaluation and Grading

Final grades are based on grades earned for each of the midterm exam, the lab exams and final theory exam.

Letter grades are based on the following final numeric grades:

A^{+} = 95 - 100

A = 90- less than 95

B^{+} = 85- less than 90

B = 80- less than 85

C^{+} = 75- less than 80

C = 70- less than 75

D^{+} = 65- less than 70

D = 60- less than 65

F = 59 and below

Prior knowledge and skills required for this course:

The ability to fully comprehend and appreciate the fundamentals of physiology requires a background in basics of physiology, electrophysiology & anatomy (Approach to medical sciences).

RECOMMENDED TEXTBOOKS:

The department recommends the following textbooks:

i) Essentials of human physiology for pharmacy
ii) Medical Physiology by Guyton, A. C.
iii) Textbook of physiology by Tortora GR & Grabowski SR.
iv) Concise Human physiology By M.Y.Sukkar etal.

Recommended reading/ resources

1. http://www.uptodate.com/contents/search
2. www.Elearn.uqu.edu.sa

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COURSE DESCRIPTION AND ORGANIZATION

This course in physiology aims to introduce students to the physiological concepts of the functions of body systems with emphasis on clinical relevance. This course consists of:

1) Physiology of Respiration
2) Neuro-muscular physiology
3) Body fluids, Cardiovascular Physiology, and Blood
4) Gastro-intestinal Physiology

This course is taught to second year Pharmacy students and it consists of lectures, practical, tutorials, occasional assignments, and seminars.

Course subjects of Physiology I:

Course/subject	No. of hours for Lectures	No. of hours for Practicals
Physiology of Respiration	6	3
Physiology of muscle and nerve	6	3
Body fluid	2	1
Physiology of CVS	6	3
Physiology of blood	2	1
Physiology of digestive system	6	3
Total	**28**	**14**

Course structure of Physiology I:

Learn activity	Time allocated
Lecturing	28 h
Practical,	14 h
Tutorials, case study and assignments	6 h
Directed Self-Learning (PPT)	4 h
Total	52 h

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Course contents:

PHYSIOLOGY OF RESPIRATION

The course covers the general functions of the respiratory system but concentrates mainly on the role of the system as a gas exchange organ. This involves a consideration of the principles of the mechanics of breathing, ventilation, gas transfer, gas transport in blood, and the regulation of ventilation.

Specific Objectives
At the completion of this chapter, students are expected to know:

Introduction

Major functions of the respiratory system.
The symbols used in respiratory system.
Essential gas laws as applied to gas transport and diffusion of gases across membranes.
Functional anatomy of airways and lungs.
Basic mechanisms of ventilation - inspiration and expiration, role of thoracic cage in ventilation.

Biophysics of Ventilation:

The relationship of pressure changes to lung volume.
Important (elastic and non-elastic) properties of thoracic cage, application of above to disorders of chest injuries, rib fractures, chest deformities etc.
General function of the airways. Airway caliber changes, airway resistance and effect of changes on ventilation, e.g. bronchial asthma.
The elastic and non-elastic properties of the lungs and relationship to pulmonary function in health and disease, e.g. emphysema, fibrosis.
Functional importance of surfactant in surface tension changes, the changes in lung expansion that occurs at birth, the pathophysiology of hyaline membrane disease.

Lung Volumes and Capacities:

The principles of spirometry.
Measurement and normal values of lung volumes and capacities.

Ventilation:

The concept of dead space - both anatomical and physiological.
Alveolar space and ventilation.
Gas tension in air, alveoli, blood and tissues, and changes with altered ventilation, e.g. hypoventilation, hyperventilation etc.

Pulmonary Circulation:

The functional anatomy of the pulmonary vascular bed.
Pressure changes along the pulmonary vasculature - importance and relationship to function.

Ventilation-Perfusion Relations:

Effect of gravity on alveoli and blood distribution in the lungs.
Effect of gravity on air distribution in inspiration.
Ventilation-perfusion relations for whole lung and regions of the lungs - base as opposed to the apex .

Oxygen Transport:

Revise main factors governing directional movement of O_2.
Modes of O_2 transport in blood.
Importance of hemoglobin as carrier.
Principles and functional significance of the O_2-Hb dissociation curve and factors affecting it - pCO_2, H^+.
Application of curve to O_2 uptake at the lungs and delivery to tissues.
Structural changes in Hb molecule - HbS, HbF, myoglobin etc. and effects on O_2 transport.

CO_2 Transport:

Main factors governing movement of CO_2.
Modes of transport in blood.
Role of RBC, the CO_2 - dissociation curve its difference from the CO_2 dissociation curve - the chloride shift, and the Haldane effect.

Control of Ventilation:

General organization of control of ventilation.
Chemical and neural factors which govern ventilation.
Peripheral and central chemoreceptors - location and functional differences.
Central regulation - organization of respiratory center, influences of both peripheral (pulmonary and extrapulmonary) afferents and central modulation.

PHYSIOLOGY of MUSCLE & NERVE:

At the completion of this course, students are expected to have clear knowledge of the fundamentals of excitability, the nerve action potential and its physiological characteristics; synaptic transmission; excitation and contraction of skeletal and smooth muscles as well as neuromuscular transmission.

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Specific Objectives:
At the completion of this chapter, students are expected to be able to:

Nerve:
- Define resting membrane potential and recognize it as the basis of excitability.
- State the factors responsible for its genesis and maintenance and their relative importance.
- Draw an annotated diagram of nerve action potential and explain the ionic bases of its parts.
- Describe, with the aid of diagrams, the propagation of action potentials in myelinated and non-myelinated nerves.
- State and explain important physiological principles that govern nerve function (strength-duration relationship; all-or-none law).
- Describe physiological properties of mixed nerves - velocity of impulse conduction and the compound action potential.
- Describe the functional anatomy of the synapse and explain the electrical and ionic events in synaptic transmission.

Muscle:
- Classify muscles, structurally and functionally.
- Describe the structural organization of skeletal muscle from whole muscle to the level of the contractile filaments (sarcomere).
- Describe the biochemical composition of skeletal muscle and state the function of the contractile and regulatory proteins.
- State the sliding filament mechanism and describe the band changes that accompany shortening contractions.
- Describe the cross-bridge theory of force generation and state the key biochemical reactions that occur during contraction and relaxation.
- Describe, with the aid of a diagram, the process of excitation-contraction coupling.
- State the electrical characteristics of skeletal muscle and contrast them with those of nerve.
- Describe the major mechanical properties of skeletal muscle.
- Relate the above mechanical properties to in-vivo situations.
- Describe the length-tension relationship at sarcomere and whole muscle levels and load-velocity relationship and relate both to in-vivo situations.
- Distinguish between isometric, isotonic and lengthening contractions and apply them to in-vivo situations.
- Draw an annotated diagram of the neuromuscular junction and describe the process of neuromuscular transmission.
- Outline the sources, use and output of energy during skeletal muscle contraction.
- Classify smooth muscle.
- Describe the structure and functional characteristics of visceral smooth muscle and compare them with those of skeletal muscle.

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BODY FLUIDS:

The student should understand that the body may be viewed as a system of fluid compartments separated by membranes, and to appreciate the mechanisms which determine the volume and composition of the various compartments.

Specific Objectives:

At the completion of this chapter, students are expected to:

I. Quantity and Composition of the Intracellular (ICF) and Extracellular Fluid (ECF):

- Define the major body fluid compartments:

Total body water	(TBW)	Intestinal fluid	(ISF)
Intracellular fluid	(ICF)	Blood plasma	(PV)
Extracellular fluid	(ECF)	(Plasma volume)	

Identify the "barriers" which divide the total body water into these various compartments.

- State size of each compartment as a percentage of body weight and in absolute magnitude (liters) for a 70 kg man:
  TBW = 60%, ECF = 20%, ICF = 40%, PV = 4%, ISF = 16%
- Give the approximate normal concentration in ECF of: Na^+, K^+, Ca^{++}, HCO_3^-, and Cl^-, and know that the predominant anions in the ICF are organic/inorganic phosphate (most), and proteins (2^{nd} most).
- Know relation of total mass of an ion present in a compartment, volumes of the compartment, and concentration of the ion in the compartment; i.e., given any two of these values for a particular ion and compartment can calculate the third.
- Define hematocrit and know approximate normal value; know relation of red cell volume, plasma volume, blood volume, hematocrit, and can calculate all four volumes, given data for any two.
- Define and understand the dilution principle for measurement of compartments; identify volumes measured by: Cr^{51} red cells, Evans blue, radioactive Na^+ inulin, ^3H_2O, and other molecules/ions whose distribution in the body is otherwise known.

II. Osmolarity of Body Fluids:

- Define osmotic pressure. State the determinants of osmotic pressure.
- Define osmoles, know significance of dissociating vs. non-dissociating solutes.
- Know relationship of osmotic pressure to osmolarity.
- Know that normal body fluid osmolarity is about 300 mOsm.

- Define isotonic, hypotonic, hypertonic, isosmotic, hypo-osmotic, hyperosmotic. State that each term applies to any given solution.

CARDIOVASCULAR PHYSIOLOGY

This chapter deals with the heart and the circulation system. At the end of this chapter, the students are expected to be able to explain how the heart works as a pump and the role of the chambers, valves and the muscle in that. In the late part of this course, the student will be introduced to the physics of hemodynamics and the regulation of circulation. This will enable the student to understand the responses of cardiovascular system to stresses, e.g. hemorrhage and exercise. In addition, during this course, the student will acquire basic preliminary skills in using laboratory and bedside techniques commonly encountered in clinical cardiology, e.g. recording an E.C.G., measuring blood pressure and pulse.

Specific Objectives:

At the completion of this chapter, students are expected to be able to:

Functional Anatomy of the Heart

Describe the components of the cardiovascular system and identify the function of each component.
Describe the morphology of the heart and understand the role of valves in the heart.
Distinguish between the three types of cardiac muscle cells (pacemaker, conducting, contracting) which generate the force of systole.
Identify the functional role of intercalated disks and all or none principal as it applies to the heart.
Describe the nerve supply of the hart and state the functional significance of it.
Identify the cardiac receptors and state their functional significance.
Describe the blood supply of the heart.

Functional Properties of Pacemaker, Conductive Tissue and Myocardium

Describe the conductive system of the heart.
Describe the transmission of cardiac impulse through the heart.
Identify the pacemaker concept of the heart and the normal locus of the pacemaker.
Recognize the possibility of and identify the mechanism of abnormal pacemakers within the heart.
Describe the form, ionic bases and functional significance of a pacemaker potential.
Describe the form and ionic bases of an action potential recorded from a single myocardial muscle cell.
Explain why the heart cannot be tetanized.
State Starling's law of the heart.
State the parameters of the Starling's curve which correspond to the initial length and tension in the length tension diagram of skeletal muscle.
Correlate the length tension relationship in Starling's law with ventricular

volume and pressure changes.
State and explain the mechanisms of the effects of vagal and cardiac sympathetic nerves on heart rate and force of contraction.
Indicate a neurotransmitter with positive chronotropic action, negative chronotropic action,& positive inotropic action.

Cardiac Cycle:

Define systole and diastole and give their approximate duration at rest.
Describe the pressure and volume changes in the atria, ventricles, pulmonary artery and aorta during the six phases of the cardiac cycle.
Identify end-diastolic, end-systolic and stroke volumes, their typical values at rest and recognize the variabilities of these values.
Recognize the aortic and left ventricular pressure curves during the cardiac-cycle. Identify systolic and diastolic pressures, their typical values and dicrotic notch and its cause.
Identify the functional significance of atrial contraction.

Cardiac Output:

Define cardiac output and give the basic formula that indicates its primary determinants.
State normal values for cardiac output and index and their variance with age, body posture and metabolic rate.
Recognize intrinsic mechanisms of autoregulation of the heart to altered venous return and autonomic innervation as basic means by which cardiac function is regulated.
State and explain the effects of sympathetic and parasympathetic stimulation on the cardiac output.
Use Starling's law of the heart to explain the relationship between venous return and cardiac output.
State 6 factors, which affect venous return.
Recognize the normal role of peripheral resistance in determining venous return and cardiac output when arterial pressure remains about normal and the consequences of failure to maintain arterial pressure.
State and explain the effects of circulating catecholamines on cardiac output.
Identify ventricular function curves, their significance and factors producing hypoeffective or hypereffective hearts.

Hemodynamics:

Define flow and state its relationship to pressure and resistance.
Identify resistance, means of its determination, and the peripheral resistance Unit, and typical values of total peripheral and total pulmonary resistance at rest.
Identify the relationship of vascular resistance to vessel diameter, vessel length and blood viscosity.
Recognize the relationship between vessel diameter and flow.
Define systolic blood pressure, diastolic blood pressure, mean circulatory

pressure and recognize their normal values.
Identify the relationship of mean pressure to gravity, blood volume, cardiac output and peripheral resistance.

The Systemic Circulation:

Recognize the general structural design and functions of the systemic and pulmonary circulation.
Identify component functions of the aorta and elastic arteries, muscular arteries, arterioles, capillaries, venules and veins.
Define velocity of blood flow and state its relationship to the total cross sectional area of the vascular system.
Identify the progression of mean and pulse pressure through the systemic circulation and their relationship to vascular resistance.
Identify systolic, diastolic and mean pressure for the aorta, mean capillary and venacaval pressures and the locus of highest resistance among cardiovascular system.
Identify normal arterial pulse contour and the diacrotic notch.
Identify radial pulse, the rate, rhythm and volume.
Recognize the relationship between pulse volume and pulse pressure.
Define tachycardia and bradycardia giving examples in each case.

The Veins and their Functions:

Recognize the collapsible nature of veins and its effects on peripheral venous resistance and pressure.
Recognize the potential reservoir function of veins and its influence on the circulatory filling pressure.
Identify the effects of varying blood volume, respiration, heart failure and increased intra-abdominal pressure on central venous pressure.
Recall the factors affecting venous return.

Regulation of Arterial Blood Pressure:

Recall definitions of SBP, DBP, and mean pressure and pulse pressure.
Recognize their normal ranges and their relationship to age.
Identify an appropriate method for measurement of blood pressure in humans and explain the mechanism involved.
Recognize the comparative constancy of arterial blood pressure versus cardiac output and peripheral resistance.
Contrast the general characteristics of rapidly acting control mechanisms versus the long term control mechanism for the regulation of arterial blood pressure.
Describe the physiological anatomy of baroreceptors, two principle areas of their location and their afferent nerves.
State the response of baroreceptors to pressure, their effect on cardioinhibitory and vasomotor neurons and their resultant influence on the cardiovascular system.

Identify the carotid sinus syndrome.
Describe two major locations of volume receptors and their afferent nerves.
Recognize noradrenaline-adrenaline, renin-angiotensin and ADH mechanisms for the rapid control of arterial pressure. Identify the significant characteristics of each of these control mechanisms.
Identify the long-term pressure control mechanisms and the relative importance of these mechanisms as controllers of arterial pressure.
Recognize the sequences and significant characteristics of intermediate steps involved in the renal body fluid feedback control system for the regulation of arterial blood pressure.
Identify the roles of the rennin angiotensin system and of aldosterone in the long term regulation of arterial blood pressure.
Acquire the skill of measuring blood pressure in humans using mercury sphygmomanometer.

PHYSIOLOGY OF BLOOD

This course deals with blood. At the end of this course the student will be able to describe the structure, formation and functions of different blood cells. In addition, the student will be able to understand the classification of blood groups and appreciate their roles in blood transfusion. Also, during this course, the student will recognize the mechanism of homeostasis and blood coagulation. Throughout the course, the student will acquire skills in using laboratory techniques commonly encountered in clinical hematology.

Specific Objectives:
At the completion of this chapter, students are expected to be able to:

General Considerations:
State three major functions of blood.
Recognize the two major constituents of blood and indicate in percent the contribution of each constituent to the total blood volume.
Describe the composition of plasma.
Identify plasma proteins, types, concentration and sites of production.
State the major functions of plasma proteins.

The Erythrocyte:
Describe the structure of red blood corpuscle.
State two major functions of RBCs.
State the main stimulus to red blood cell production.
State the average life span of red blood cells and describe the process of red blood cell destruction.
Define anemia and polycythemia.
Estimate hemoglobin concentration, RBC concentration and hematocrit in a human: blood using cyanomethaemoglobin method, hemocytometer and

Microhematocrit tube and centrifuge respectively.
Derive mean corpuscular volume (MCV), mean corpuscular hemoglobin concentration (MCHC) and mean corpuscular hemoglobin (MCH) from the estimated Hb, RBC and hematocrit.
Recognize the importance of MCV, MCH and MCH in the investigation of a patient with anemia.

The Leukocytes and Reticulo-endothelial System:

Characterize leukocytes and platelets with regard to their structure and differential blood concentration.
Estimate total leukocyte concentration in a human blood using hemocytometer.
Identify the general significance of cells of the reticule-endothelial system.
The differential roles of macrophages located in various body tissues and their probable derivation.

Blood Groups and Blood Transfusion:

Recognize the antigenic nature of the blood constituents and their significance in blood transfusion.
Understand the classification of blood groups (mainly ABO and Rh), their relative prevalence and their mode of inheritance.
Acquire the skill of determining blood groups (ABO and Rh) in human blood.
Recognize the clinical importance of blood transfusion.
Identify the nature and consequences of transfusion reaction.
Explain what is meant by cross matching & indicate the significance of cross-matching in blood transfusion.
Define the terms ‘universal donor’ and ‘universal recipient’ and recognize the limitations of the term universal.

Hemeostasis and Blood Coagulation:

Describe the process of blood clotting (homeostasis).
Recognize the differences between intrinsic and extrinsic pathways of blood clotting.
Recognize and understand the factors, which prevent blood from clotting inside healthy blood vessels.
State the major anticoagulants available for clinical use (in vivo and in vitro), They’re utility and their mode of actions.
Recognize the existence of common blood coagulation tests (bleeding time, clotting time, prothrombin time) that are used for the determination and identification of abnormalities of hemeostasis.
Identify typical values, methods of determination and significance.

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GASTROINTESTINAL PHYSIOLOGY

By the end of this course, the student should learn sufficient basic gastrointestinal physiology. Through lectures, practicals, tutorials, and assignments, he should be able to describe the functions and regulation of the gastrointestinal tract.

Specific Objectives:

At the completion of this chapter, students should be able to:

Functions and Regulation of GI Tract

Describe the overall role of the gastrointestinal system with respect to the absorption of nutrients and excretion of waste products.
State the four general processes associated with gastrointestinal function.
Define the cephalic, gastric and intestinal phases of GI tract regulation.
Name and locate the myenteric and submucosal plexus.
Describe the relation between the autonomic nervous system, the enteric nervous system and the effectors organs of the GI tract.
Describe the location of the endocrine cells secreting Gastrin, secretin, and cholecystokinin (CCK).
Describe the similarities in structure (identifies related hormones - does not memorize amino acid sequences) between Gastrin, secretin, and CCK, and between these and other hormones.
Be aware of the existence of the following regulatory peptides: gastric inhibitory peptide (GIP), motilin, Gastrin-releasing peptide (GRP), somatostatin, substance P and vasoactive peptide (VIP).

Salivary Gland:

State the major components present in salivary secretions.
State the substrates and digestion products of salivary amylase.
Describe the function of salivary mucus.
State the types of stimuli that increase salivary secretion.

Esophagus:

Describe the function of the upper esophageal sphincter (UES) and lower esophageal sphincter (LES).
State the stimulus that initiates the swallowing sequence.

Stomach:

State the functions of the stomach.
Identify the contents of the parietal cell secretions.
Identify the contents of chief cell secretion.
State the steps in HCL secretion by parietal cells.
Describe the alkaline tide accompanying HCl secretion.
Describe the role of HCl in gastric digestion.
State the effects of ingested protein on gastric acidity.

Describe the function of gastric mucus.
State the mechanism of activating pepsinogen.
Describe the digestion products of pepsin activity.
Describe the relation between the stomach, intrinsic factor and pernicious anemia.
Describe the stimuli and possible pathways giving rise to the cephalic, gastric and intestinal phases of HCl secretion.
Identify the stimuli that increase Gastrin release.
Identify the stimuli that inhibit Gastrin release.
Define receptive relaxation of the stomach and states mechanism.
Describe the origin and progression of peristaltic waves across the body and antrum of the stomach.
Describe the effects of peristalsis on the mixing and propulsion of stomach contents.
State the duodenal stimuli that alter the rate of gastric emptying.

Pancreas:

List the major contents of pancreatic secretions.
Describe the mechanisms by which chyme is neutralized in the duodenum.
Describe the mechanism by which pancreatic zymogen are activated in the small intestine.
State the stimuli that release secretin.
State the stimuli that release CCK.
State the effects of secretin and CCK on pancreatic secretion.
State the effects of the autonomic nerves to the pancreatic secretion.

Bile:

State the composition of bile as secreted by the liver.
Describe the effects of CCK on the contraction of the gallbladder and the sphincter of Oddi.
State the effects of CCK and secretin on the composition of bile entering the small intestine.
Describe the amphipathic structure of bile acids and their role in emulsification of fats.

Small Intestine:

State the function of the small intestine.
Describe the composition and sources of intestinal secretion.
State four sources of digestive enzymes that contribute to the digestion of organic nutrients prior to their absorption.
Describe the role of the microvilli, the unstirred layer, and tight junctions in determining the rate at which a given nutrient is absorbed.

Large Intestine:

Describe the functions of the colon.
Describe the motility of the colon; segmentation contractions, peristaltic waves, gastro-ileal reflex and the mass action contraction.
State the mechanism of colonic absorption of salt and water.
State the mechanism of colonic potassium and bicarbonate secretion.
State the effect of aldosterone on sodium and potassium transport across the colonic epithelium.
Define "dietary fiber".

Digestion and Absorption of Carbohydrates:

State the forms of the major ingested carbohydrates.
State the forms of the carbohydrates entering the duodenum from the stomach.
Describe the role of pancreas in carbohydrate digestion.
Identify and describes the role of the brush-border enzymes involved in carbohydrate digestion.
Describe the pathways by which glucose, galactose and fructose cross the apical and basolateral membranes of enterocytes.

Digestion and Absorption of Proteins:

Describe the state of the proteins entering the duodenum from the stomach.
Describe the role of the pancreas in protein digestion.
Identify and describes the role of the brush-border enzymes involved in protein digestion.
Describe the mechanism by which amino acids, di- and tripeptides are absorbed.

Digestion and Absorption of Lipids:

Describe the state of ingested lipids.
Describe the role of the pancreas in lipid digestion.
Describe the products of fat digestion by pancreatic lipase.
Describe the role of micelles in lipid absorption.
Describe the composition and formation of chylomicrons.
Describe the release of chylomicrons across the basolateral membrane of enterocytes.

Absorption of Vitamins:

Describe the absorption of fat-soluble vitamins.
Describe the absorption of water-soluble vitamins.
Describe the role of intrinsic factor in absorption of vitamin B12.

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Absorption of Water and Electrolytes:

Describe the changes in osmolarity that occur in chyme as it passes from the stomach to the duodenum and gives the explanation for these changes.
Describe the pathways by which sodium ions are absorbed in the small intestine.
Describe the relation between sodium absorption and water absorption.
Describe the absorption of iron.
Describe the absorption of calcium.

Intestinal Motility:

- Describe the pattern of intestinal motility seen during the absorptive phase (segmentation).
- Describe the pattern of intestinal motility seen during the post-absorptive phase between meals (the migrating motility complex, MMC).
- Describe the effects of parasympathetic and sympathetic nervous activity on small intestinal motility.
- Describe the effects of distention on small intestinal motility.
- Define the gastro-ileal reflex.
- State effects of increased pressure in the ileum and cecum on the ileocecal sphincter.